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LLNL-TR-667375

Instron Investigation Testing Report

S. Franco

February 17, 2015

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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Instron Testing Investigations

- **Investigation 1:** Rotational Spike Investigation
- **Investigation 3:** Instron Machine Slipping Investigation
- **Investigation 3:** Instron Machine Rotational Compliance Investigation

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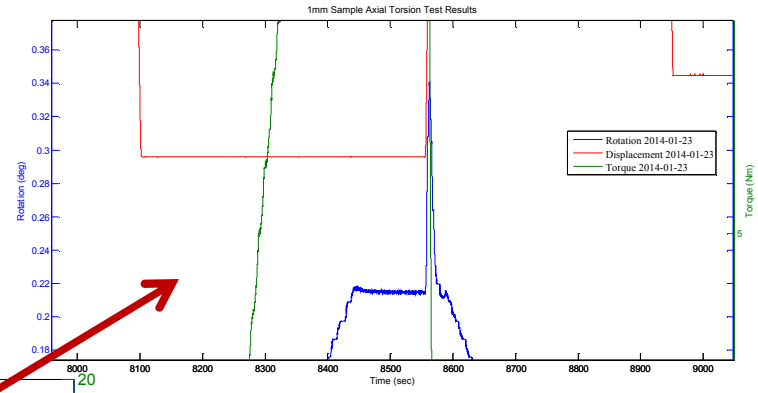
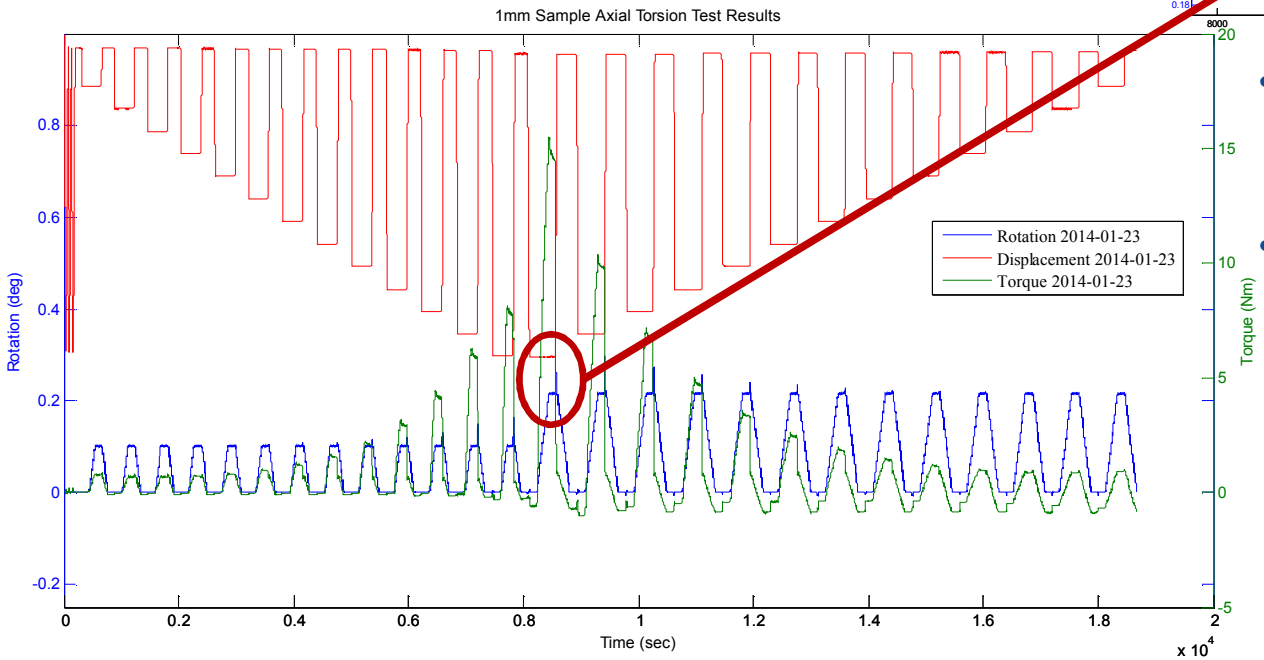
Rotation Spike Investigation

- Rotation spikes are observed when the sample is under both axial and torsion loads and then the axial load is removed.
- The spikes increase in amplitude as the axial loading increases.

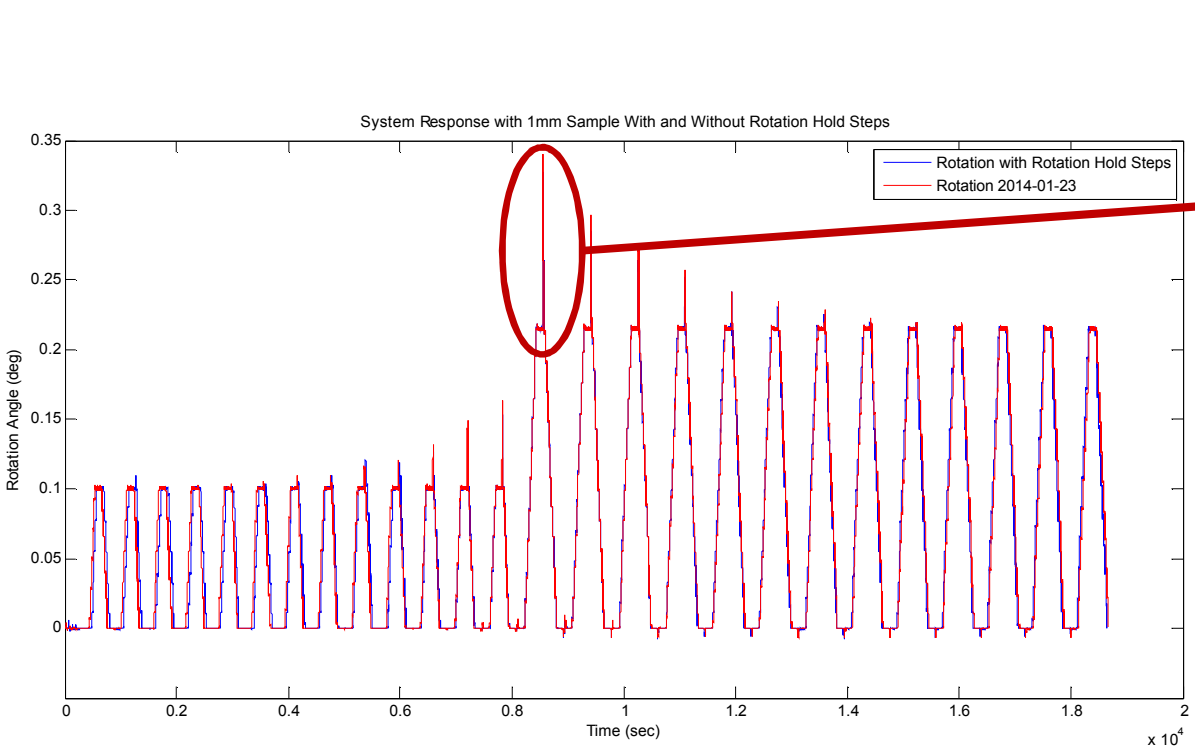


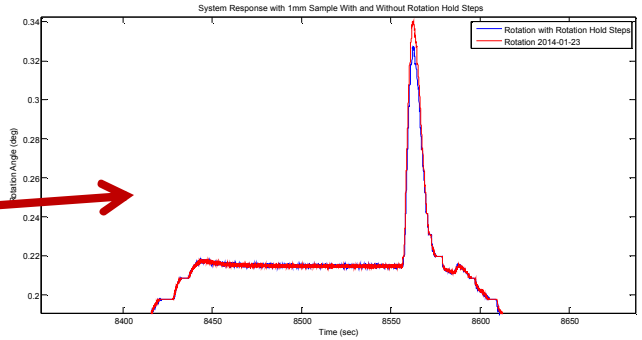


- Rotation spikes may be due to the control system of the Instron.
- There is a force output from the rotational actuator and the sudden drop off in axial load causes the actuator load output to be higher than that required to maintain the set rotational angle. There is then a lag time until this is corrected.

Rotation Spike Investigation – Add Rotation Hold

- The Instron Test Method (control steps) was modified to add Rotational Hold steps while unloading the sample axially. Previously no rotation step was defined during the axial unloading steps.
- The results showed no change in the rotational angle spikes.





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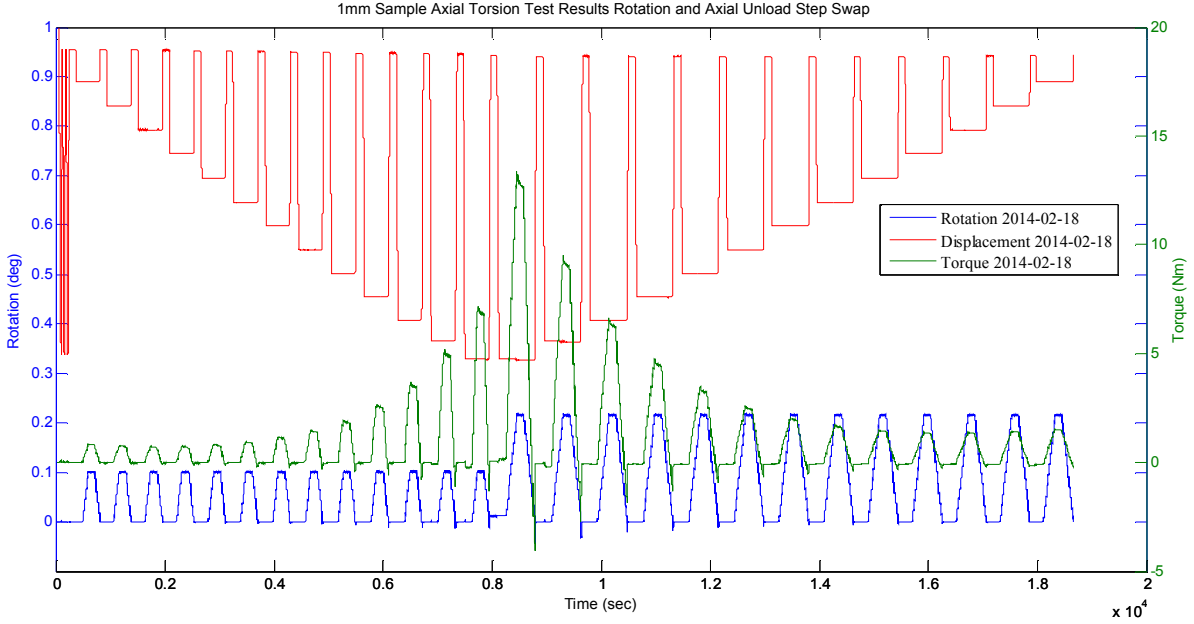
Rotation Spike Investigation – Swap Steps

- The Instron Test Method (control steps) was modified to swap the order of the axial displacement unloading and rotational unloading steps.
- The results show that the rotation spike is still present, but now a lower amplitude and opposite direction. The spike still corresponds in time to when the axial load is removed
- There is now a more apparent spike in the torque. It is also negative and the peak of the spike corresponds to the axial unloading step.



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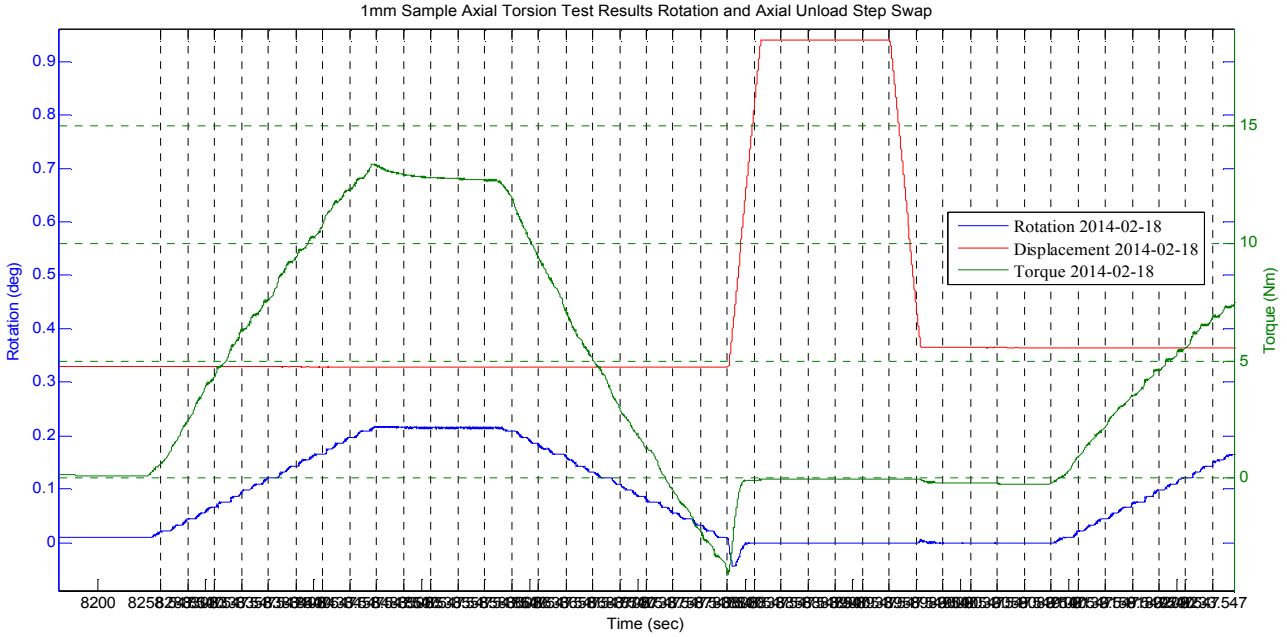
Rotation Spike Investigation – Swap Steps

- The torque goes negative before the rotation returns to zero position. This is either an indication of the non-linear properties of the material or that slipping between the platens and the sample is occurring.
- The torque does return to zero after the axial unloading step. This could be due to the material compliance increasing while not loading.
- The spike in the rotation curve could still be due to the response time of the rotation actuator.



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Rotation Spike Investigation – Conclusion

- The spikes that are seen in the rotation angle, but also sometimes in the torque data appear to be a result of the axial displacement/load being removed.
  - This is likely due to the change in the torsional load required to hold a given rotation angle during axial unloading.
  - During axial unloading, the force that the rotational actuator in the Instron machine is outputting overcomes the changing material resistance and causes the rotation angle to increase.
  - The control system cannot anticipate nor respond fast enough to prevent this rotation spike from occurring.
    - It may be possible to limit this spike if the axial displacement rate is decreased.
  - It is not apparent if these rotational spikes affect the material response after they occur or if they are merely data artifacts that are understood as being related to the Instron machine performance.

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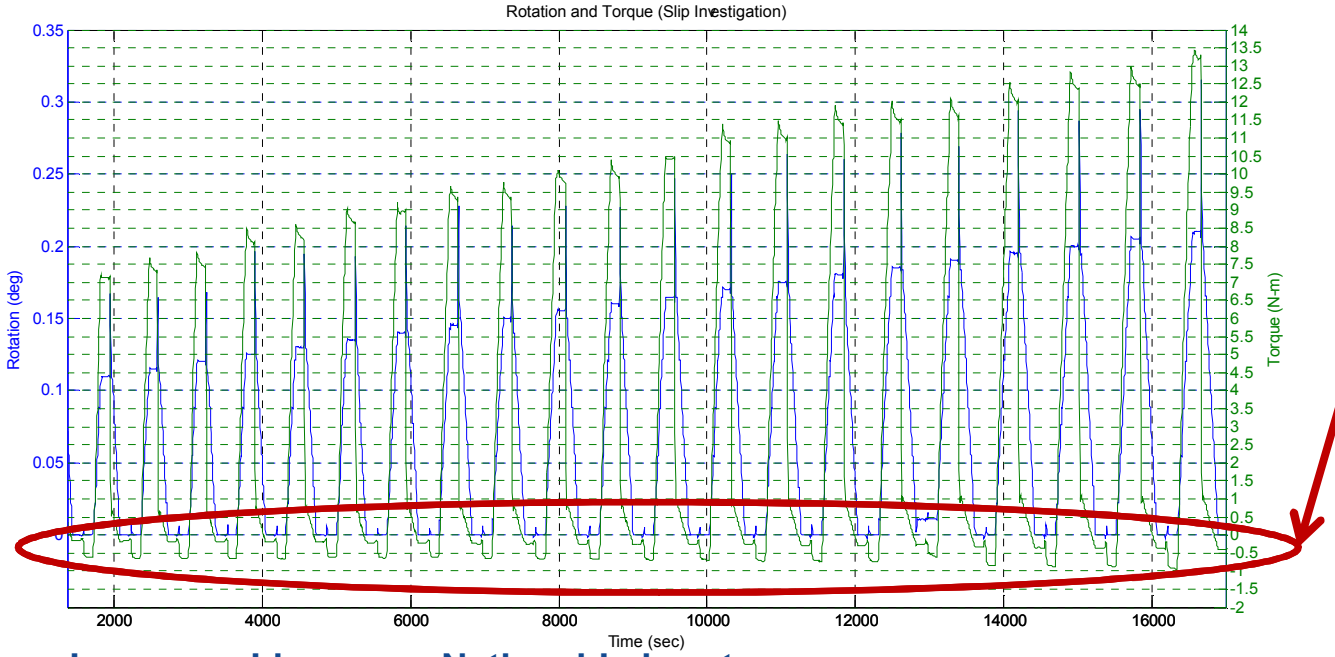
Slipping Investigation

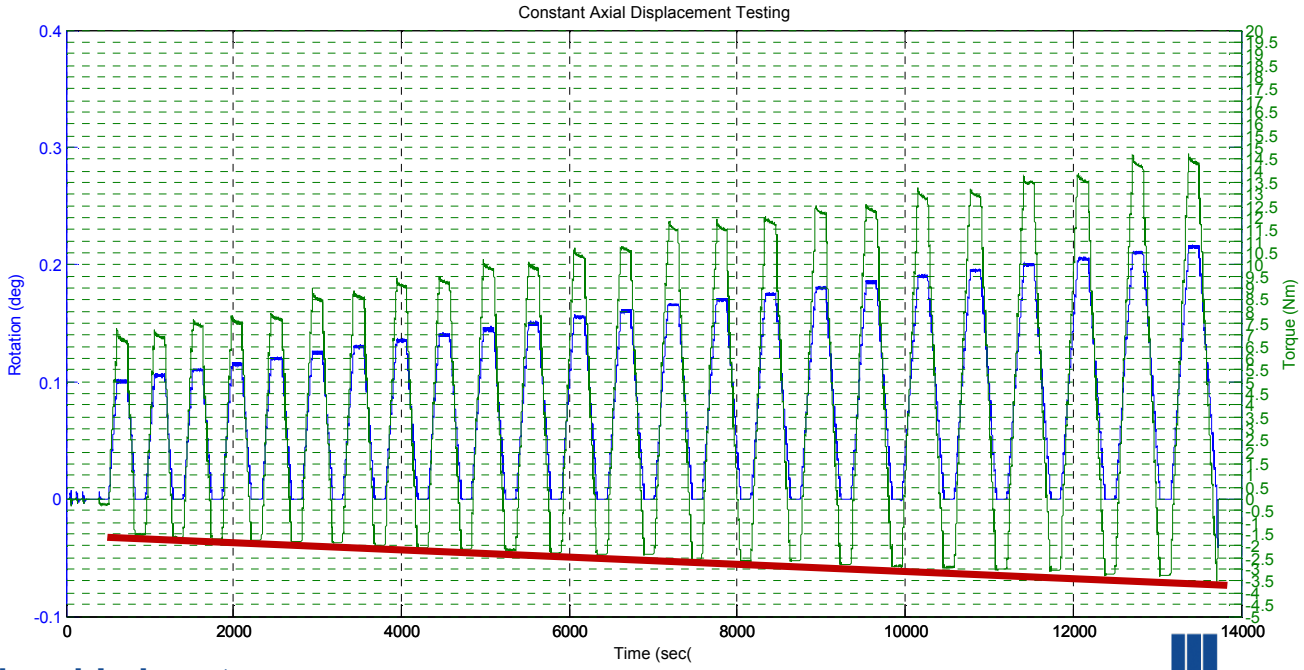
- Through the testing, it was noted that the torque value would not return to zero, but go instead through zero into the negative.
- This also appeared to get worse as the number of cycles increased.
- In order to explain this, we attempted to determine if slipping was occurring between the platens and the material sample. Slipping would explain why the torque value would get more negative as the number of cycles increased even though the rotation was returning to zero every time.



Torque becomes more negative as the number of cycles increases

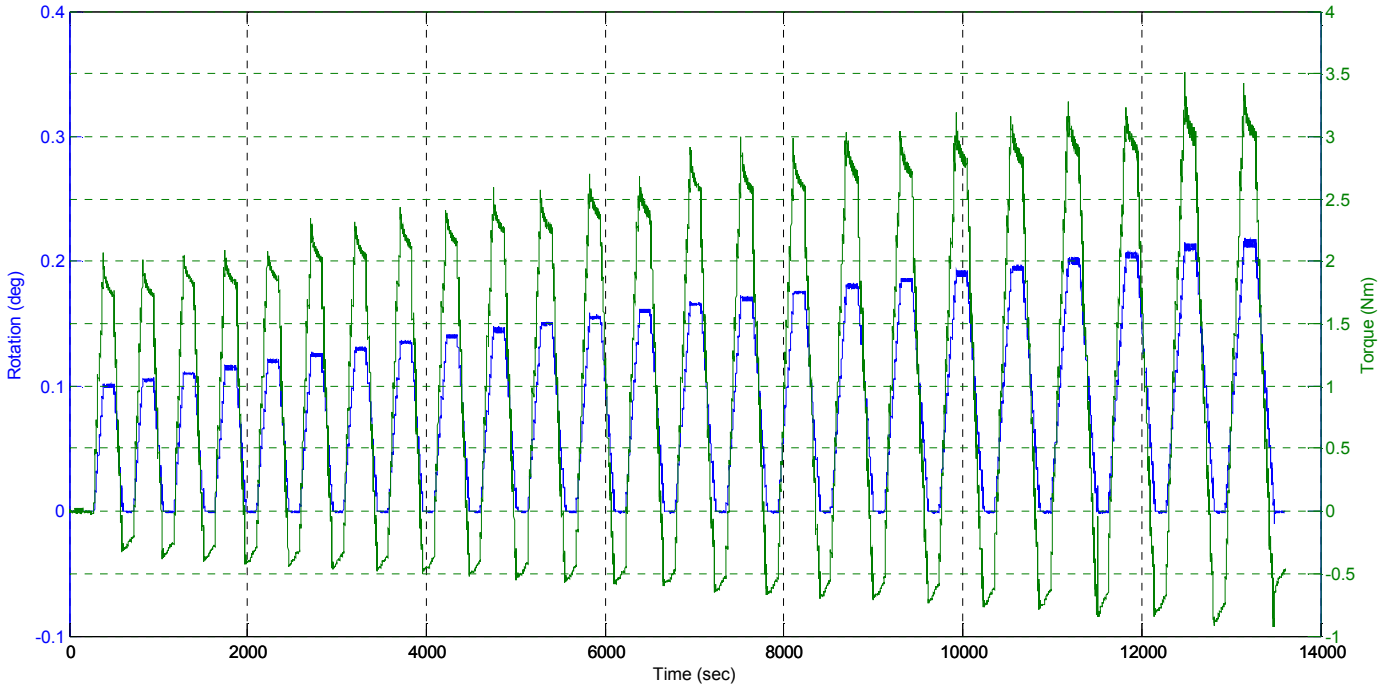
Slipping Investigation – Constant Axial Displacement, Varying Rotation

- Besides the number of cycles increasing, the previous tests also had an increasing axial displacement and therefore load with each cycle.
- In order to determine if the axial load had an effect on the torque, constant axial displacement tests were conducted. The axial displacement was applied and then held for the duration of the rotation cycles.
- The test still showed increasing negative torque values as the rotation angle increased. This result is an indicator that slipping is occurring during the tests.
- If slipping is occurring, it is happening through all tested rotation angles.
- It should be noted that the spikes in the displacement are not present due to the axial loading and unloading.



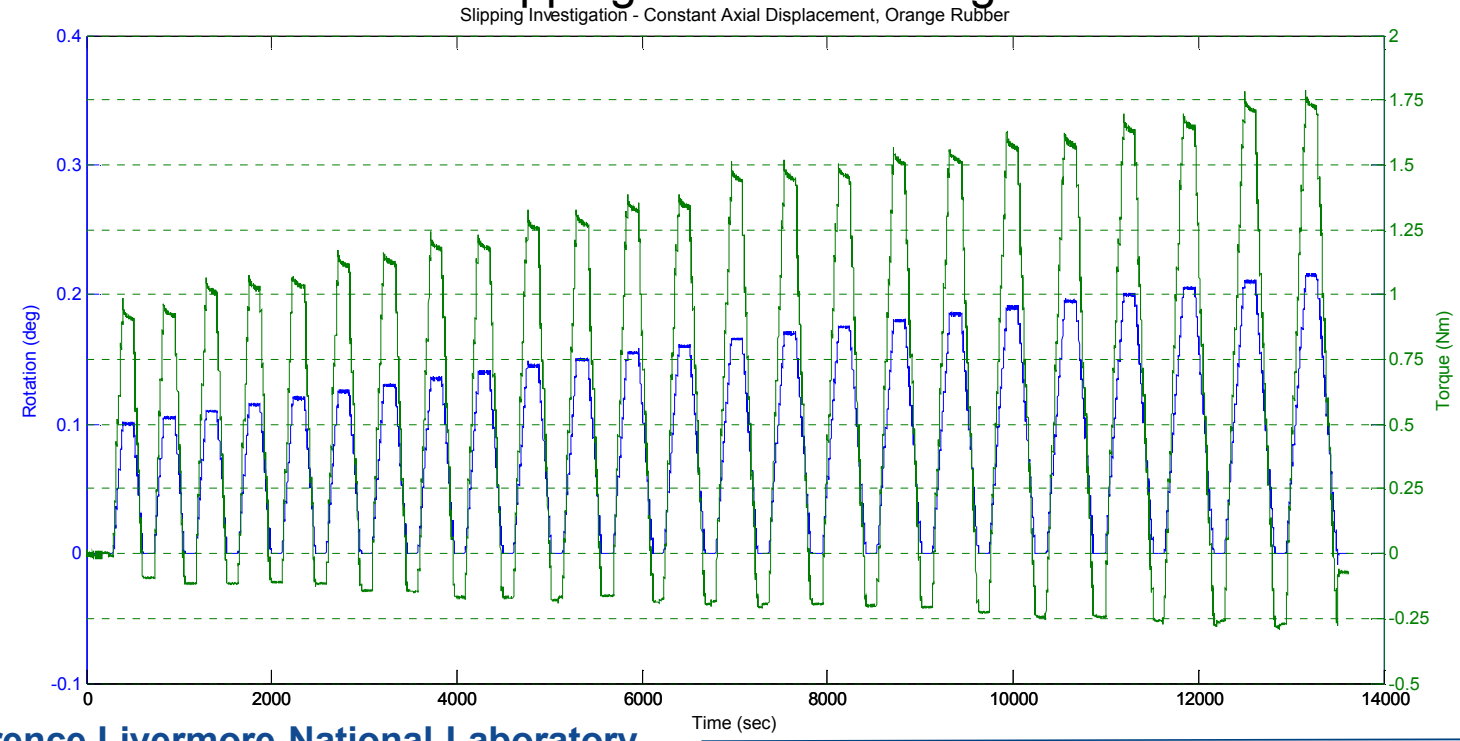
Slipping Investigation – Constant Axial Displacement, New Material 1 (Black Rubber)

- In order to see if the material under test was affecting the torque data, another material was tested in its place.
- This material was a 1.63mm thick black rubber.
- The results show that the torque still goes negative and increases with rotation angle.
- This would indicated that slipping is also occurring with this material.



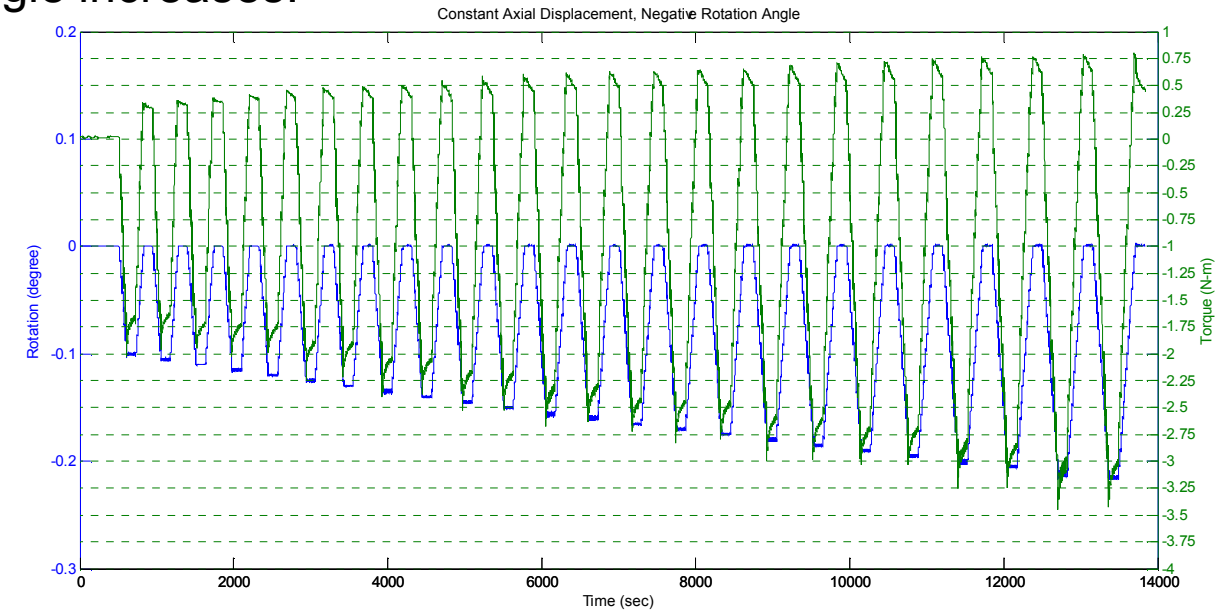
Slipping Investigation – Constant Axial Displacement, New Material 2 (Orange Rubber)

- In order to see if the material under test was affecting the torque data, another material was tested in its place.
- This material was a 1.62mm thick orange rubber.
- The results show that the torque still goes negative and increases with rotation angle.
- This would indicated that slipping is also occurring with this material.



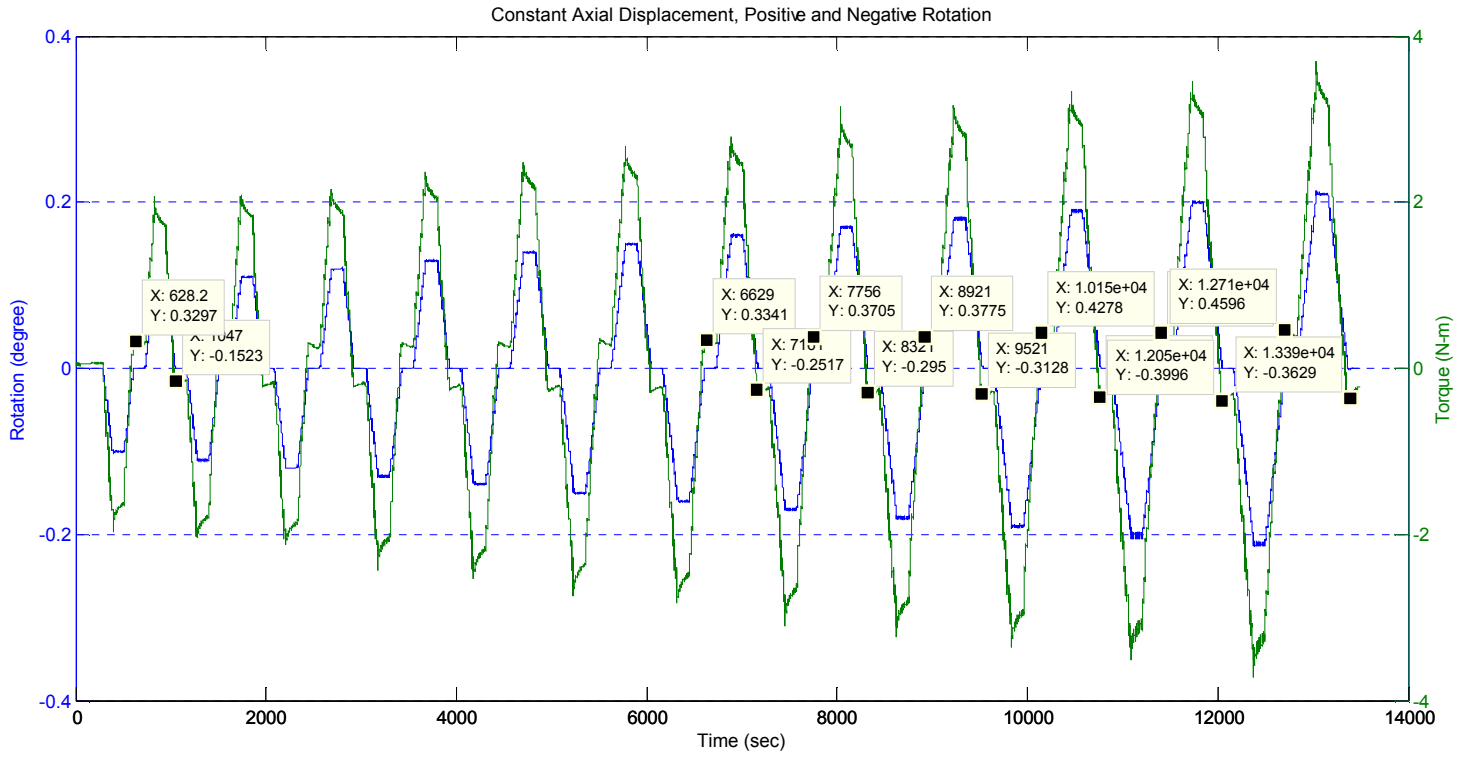
Slipping Investigation – Constant Axial Displacement, New Material Negative Rotation Only

- In order to ensure that the negative torque did not have something to do with the direction of rotation of the Instron (all tests had been completed rotating one direction), the same constant axial displacement profile was modified to rotate in the negative direction.
- This test was completed with the black rubber surrogate material because that happened to be in the machine at the time.
- The plot shows that the torque still crosses zero and gets higher as the rotation angle increases.



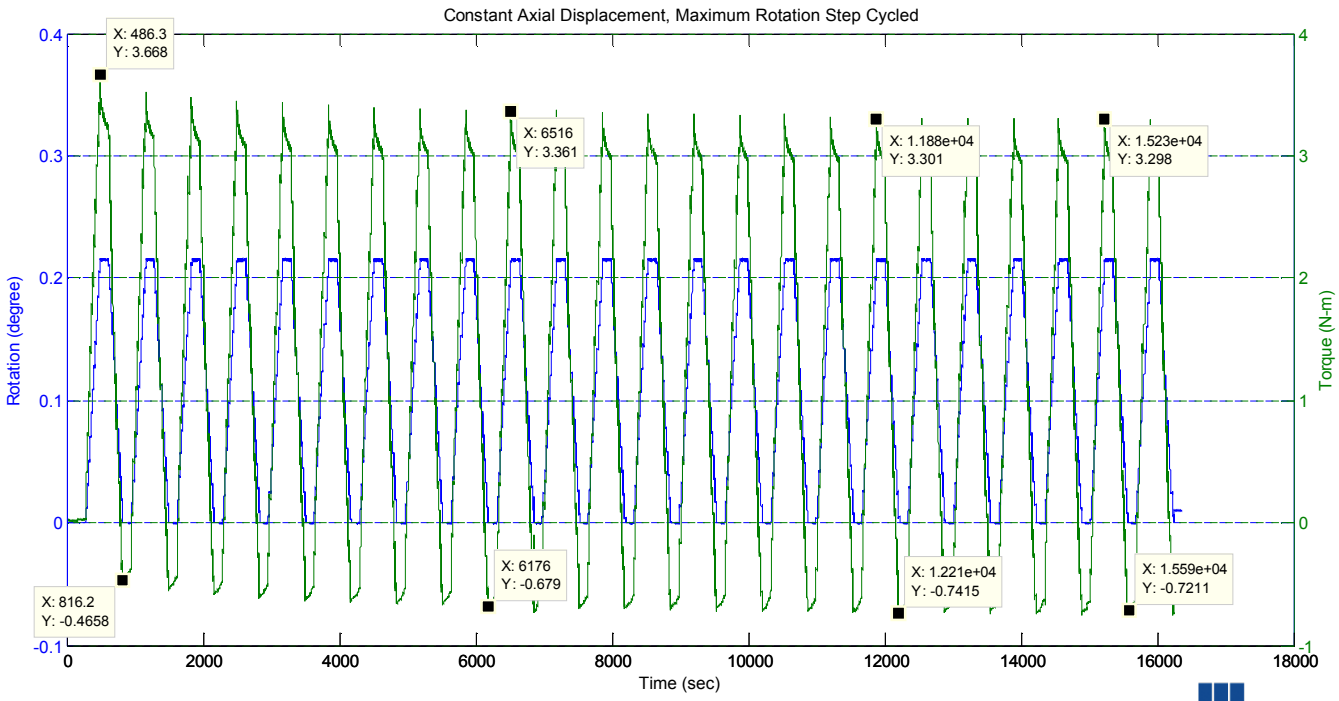
Slipping Investigation – Constant Axial Displacement, New Material Positive and Negative Rotation

- The surrogate material (black rubber) was also tested through alternating positive and negative rotations.
- The non-zero torque return was seen in all steps and still increased with rotation angle. It seemed to be slightly worse/offset from the negative rotation, but that could be from a slightly off zero calibration of the torque cell.



Slipping Investigation – Constant Axial Displacement, Maximum Rotation Step Only

- A test was conducted that just repeated that same rotation angle in one direction multiple times to see if the non-zero torque return got progressively worse or if it was stable.
- The non-zero torque return does get worse over the first 9-10 cycles and then stays about the same. This means it may be slipping a little more each time for the first 9-10 cycles.
- It is also interesting to note that the magnitude of the non-zero torque return here is about the same as that seen in the increasing rotation angle tests for the same rotation angle.



Slipping Investigation - Conclusion

- The results of the slipping investigation are still somewhat unclear.
- There is definitely something acting in an unusual way.
  - This can be explained by the test sample slipping with respect to the platens.
  - It may also be the platens slipping with respect to the push rod shafts.
  - The previous slide shows that the amount of negative torque level is tied directly to the rotation angle, but it takes a number of cycles before the negative torque becomes consistent (slipping stops).
  - One test that was not done, but that should be is to run from max rotation angle to min rotation angle and see if negative torque level changes.
- The second possibility is that the samples or machine parts are not slipping and that this is a material property that is being observed, like a permanent deformation or residual stress in the material.

Instron Machine Rotary Compliance Testing

- Axial compliance correction had been completed previously for all tests conducted, but the machine torsional compliance was assumed to be minimal.
- Unlike axial compliance, some thought had to go into how the axial compliance of the machine would be tested.
  - The easiest way to accomplish this was to remove the platens, close the gap between the upper and lower push rods and then bolt the upper and lower push rods to each other.
  - The bolts acted as shear pins and transferred the load between the upper and lower push rods.
  - There may be some error because of the compliance of the bolts, which are not normally configured like this. There are bolts that attach the platens to the push rods in the normal configuration, but the compliance may be different.
  - There is slop between the bolts and the through holes that must be taken up and it is seen by an initial rotation angle with little to no torque.
  - This setup does not take into account the compliance of the platens, but this is likely small compared to the rest of the system because of the platen dimensions .

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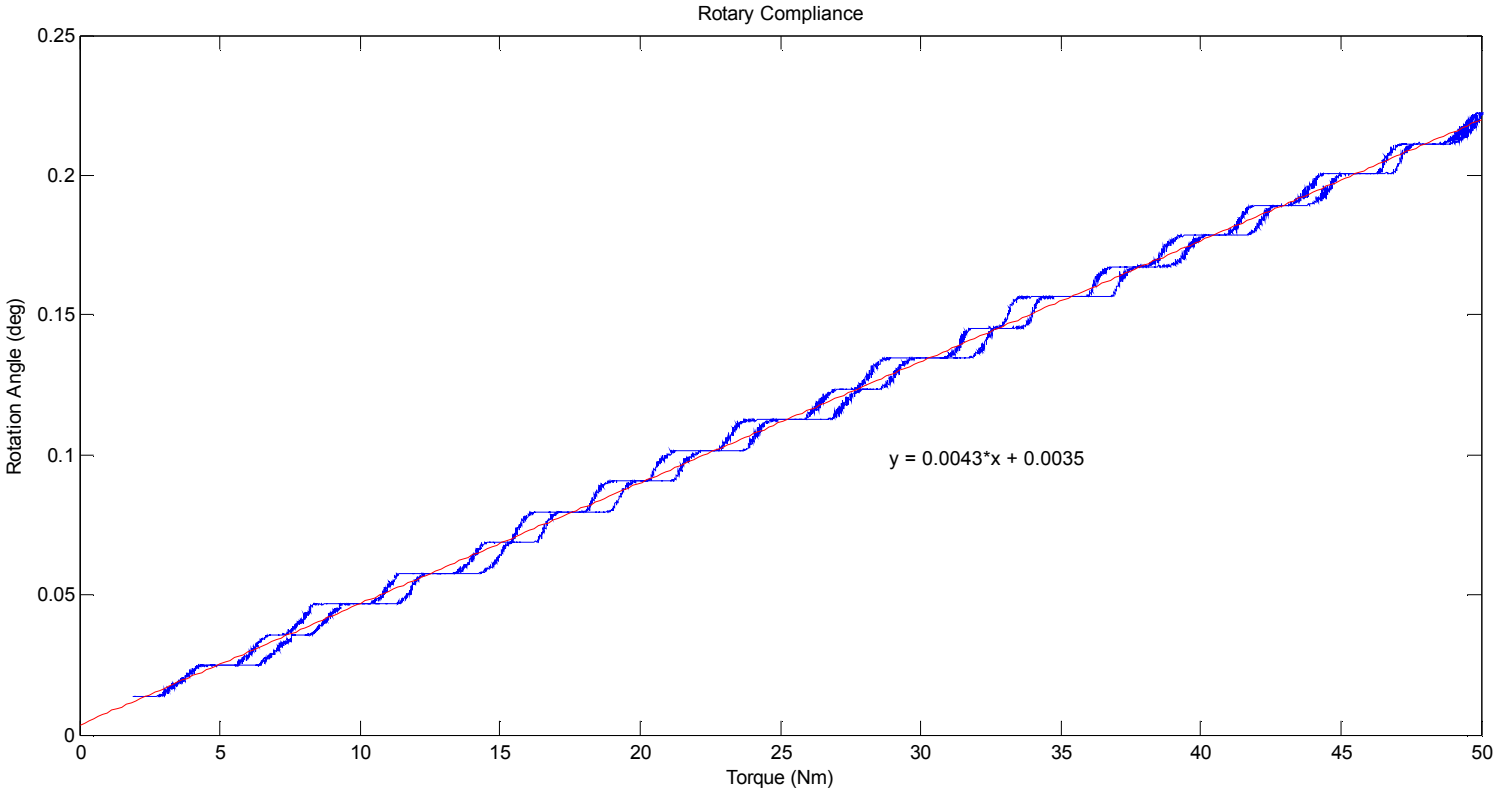
Instron Machine Rotary Compliance Testing

- The Instron rotational compliance linear curve fit is shown below.
- The maximum torque seen during the recent testing has been around 15Nm, which corresponds to a compliance of approximately 0.065 degrees, which is about 30% of the maximum angle of rotation controlled to during these tests.



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Instron Machine Rotary Compliance Testing - Conclusions

- The rotational compliance of the machine is larger than originally expected and cannot be ignored.
- The torsional compliance is likely high due to the long push rods being used in the Instron.
  - These push rods are long to allow for the use of the environmental chamber.
  - Lower rotational compliance numbers would likely be found if shorter push rods were used. We do not currently have shorter push rods for the machine.
- A better method for measuring rotational compliance should be developed.
  - At a minimum, sliding fit pins should be made to use in the place of the bolts to ensure that there is minimal slop to be taken up and it will help to more uniformly load all the pins and decrease the local compliance of the pins.
  - Thought should be put into a fixture that can include the platens in the rotational compliance measurement.
- An alternative to preforming a rotational compliance test is to measure the rotation at the sample (platens) instead of in the crosshead of the Instron. This would eliminate the need for compliance correction because the rotation measurement is made right at the sample location.